Chapter 4
Geologic Setting

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In Wyoming, the Bear River Basin drainage comprises approximately 24,106 square miles (15.43 million acres), encompassing the western edge of the state, bordering Utah and Idaho. The geologic setting for the Wyoming part of the basin is complex, including three major thrust sheets related to the Sevier Orogeny and subsequent extensional reactivation of several thrust planes during the Quaternary. A complete description of the geologic framework of the Bear River Basin must include summary accounts of the assemblages of geologic and hydrogeologic units and structural elements that define each of their geometry. To accomplish this, an extensive set of figures and maps, presented as plates, are included in this report:

Plate 1 illustrates the bedrock geology of the Bear River Basin in Wyoming, Utah, and Idaho overlain on a base map that shows highway, township, state and county data. Inset maps present the elevations of the Precambrian basement and lineaments (linear geologic features). **Appendix A** contains detailed descriptions of the geologic units shown in **Plate 1**.

Plate 2 displays an outcrop map of hydrogeologic units in the Bear River Basin developed by correlating the geospatial data of hydrogeologic units with hydrostratigraphic nomenclature charts (**Pl. 5**). Individual Bear River Basin aquifers are discussed in detail in **Chapter 7**.

Figure 4-1 illustrates thrust sheet and fault locations in the basin; Five cross sections (**Figs. 4-2** through **4-6**), included at the end of this chapter, show geologic features at selected locations (**Fig. 4-1**). Isopach maps with substantial coverage of the major aquifers in the Bear River Basin are not available.

4.1 General geologic history (Ahern and others, 1981)

The Bear River Basin contains rocks in age from Cambrian to Holocene sediments that overlie a Precambrian basement made up of igneous and metamorphic rocks. The geologic history relevant to groundwater resources of the Bear River basin is as follows:

Paleozoic rocks consist mainly of calcareous passive margin sediments. The calcareous formations are composed of crystalline dolomite and limestone. These formations generally lack solution zones, with the exception of the Madison Limestone. Quartzite, sandstone, conglomerates, mudstone, siltstone, and shale interbed within the Paleozoic carbonates.

Mesozoic sediments are typically clastic, deposited in continental shelf environments. Units in the Triassic up to the Cretaceous Mesaverde Formation are predominately shale mudstone and siltstone. However, limestone, dolomite, and sandstone also occur. The Mesaverde Formation and other rocks in the Upper Cretaceous generally include sandstone, siltstone, and shale with interbedded coal and conglomerate units.

Cenozoic rocks consist of complexly intertonguing fluvial and conglomeritic rocks. Late Paleocene and Eocene rocks are primarily mudstone and sandstone, becoming more tuffaceous towards the Miocene. Miocene and Pliocene rocks consist primarily of conglomerates, claystone, and sandstone. Quaternary rocks consist of unconsolidated sand, clay, and gravels. The unconsolidated units have numerous sources, including glacial, colluvial, and fluvial depositional facies.

4.2 Structural geology

The Bear River Basin consists of two, dominant structural features, the Thrust (or Overthrust) Belt and the Uinta Mountains. The Thrust Belt is a major continental feature, extending from British Columbia to the Uinta Mountains in Utah. The Uinta Mountains are an east-west trending range of Laramide age (35 – 80 million years ago (Ma)) that stretch eastward from the Wasatch Range in the west to the Sand Wash and Piceance basins in Colorado.

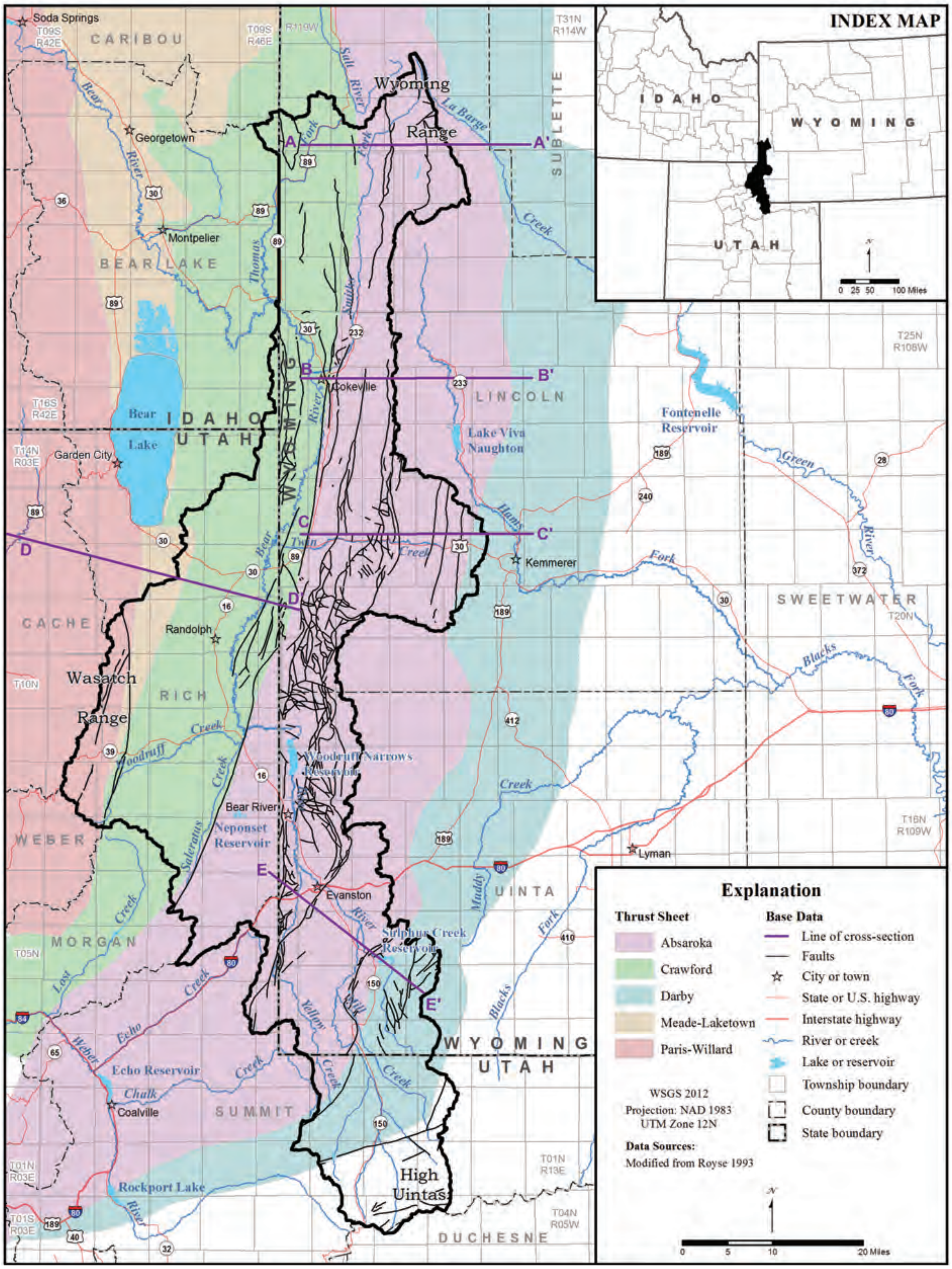


Figure 4-1. Geologic features in the Bear River Basin.

4.3 The Thrust Belt (Ahern and others, 1981)

The thrust belt in the Bear River Basin consists of an expanse of on-strike valleys and ridges with significant topographic relief—up to 1,000 feet per mile in the north. Generally, Paleozoic and Mesozoic rocks were pushed eastward along a series of low-angle, westward-dipping, imbricated faults, creating significant thrust sheets. Stratigraphic displacement along the thrust faults range from 20,000 to 40,000 feet each. Numerous second-order thrusts exist within each sheet. The sediments within each thrust sheet are intensely folded, especially in the northern portion of the basin, and in some cases strata are overturned. Major breccia zones do not exist, and the rocks are not metamorphosed. The rocks generally maintain superposition, suggesting the thrusting occurred along bedding planes. The sub-parallel ranges are bound on the east by thrust faults and on the west by younger, high-angle normal or reverse faults that are down-drop to the west. Some of the normal faults show Holocene aged displacement, including the Bear River fault zone and the Rock Creek Fault.

The formation of the Thrust Belt began during the Sevier orogeny (140 – 50 Ma). All five main thrust systems exist within the Wyoming part of the Bear River Basin and the Utah and Idaho headwater areas (**Fig. 4-1**). From oldest to youngest (west to east) they are the Paris-Willard, the Meade-Laketown, the Crawford, the Absaroka, and the Darby thrust systems.

4.3.1 Paris-Willard Thrust System (Royse, 1993)

The Paris-Willard Thrust System is the most westward, and oldest, of the thrust systems in the Overthrust Belt. It is also the highest structural thrust in the system. Only a small section of the thrust encompassing the Bear River Range is located within the Bear River Basin. The fault merges with the Meade-Willard Thrust System in the basin, cutting lower Paleozoic rocks in the Bear River Range. The merge also makes a total offset difficult to determine, but literature suggests offset of about 15 miles.

4.3.2 Meade-Laketown Thrust System (Royse, 1993)

The Meade-Laketown Thrust System in the western most portion of the basin bounds the eastern flank of the Wasatch Range. The Laketown portion of the Meade-Laketown Thrust System is located in the Bear River Basin, and includes Silurian dolomite, not found in the thrust systems to the east. The Laketown thrust is covered by Neogene fluvial beds. The emplacement of the Meade-Laketown Thrust System may be responsible for the conglomerates found in the Cretaceous Frontier Formation in the Bear River Basin.

4.3.3 Crawford Thrust System (Royse, 1993)

The Crawford Thrust System in the center of the basin dictates the majority of the basin's structure. The Crawford system thrusts Cambrian rocks over Upper Cretaceous rocks and is thought to share a common Cambrian detachment zone with the Absaroka thrust to the east. Jurassic evaporite beds act as major detachment horizons for fault offset. Displacement along the Crawford thrust is up to 20 miles in the vicinity of the Crawford Mountains and decreases to the north. The zone between the Crawford and Laketown thrust systems contains a number of thrust faults and folds in Triassic and Jurassic rocks east of Bear Lake valley.

4.3.4 Absaroka Thrust System (Royse, 1993)

The Absaroka Thrust System bounds the basin to the east, influencing the structure in the Twin Creek headwaters and near Sulphur Creek Reservoir. The Absaroka Thrust System cuts from a Cambrian to a Cretaceous detachment along a long lateral ramp. Displacement along the Absaroka Thrust System is up to 28 miles in places, decreasing to the north and south. The zone between the Absaroka and Crawford thrust systems contains numerous thrust faults and folds in Cretaceous and Jurassic rocks along the Smith's Fork.

4.3.5 Darby Thrust System (Royse, 1993)

The Darby Thrust System is the youngest and easternmost in the Overthrust Belt. The Darby thrust stretches northward from the Uinta Mountains to the Gros Ventre Range, showing an overall offset of up to 18 miles. Only a small portion of the southern edge of the Darby Thrust is found in the Bear River Basin, where the thrust fault intersects the main thrust of the Uinta Mountains. The thrust places lower Paleozoic rocks over the Archean basement.

4.4 Uinta Mountains (Hansen, 1969)

The western Uinta Mountains in northeastern Utah are an east-west trending mountain range approximately 60 miles long in northeastern Utah. Rocks in the western Uinta Mountains range from Precambrian to Quaternary in age. The Uinta Mountains were emplaced as an asymmetric anticline in the late Cretaceous during the Laramide Orogeny. The Uinta anticline was thrust northward, forming the North Flank reverse fault. There are numerous subsidiary faults within the Uinta Mountains, creating broad zones of brecciated and fractured bedrock. Subsequent glacial activity in the high Uintas deposited large expanses of unconsolidated glacial debris across much of the western Uinta Mountains.

4.5 Mineral resources

Figures 5-4, **5-7**, **5-8**, and **5-9** show the distribution of oil and gas operations and other active and historic mineral development locations within the Bear River Basin (**Section 5.6.2**). Mineral development operations require the use of groundwater and may create potential avenues for groundwater contamination. Even in areas without development, the presence of some naturally occurring minerals such as those that contain uranium, arsenic, and hydrocarbons, can, at significant concentrations, negatively impact groundwater quality. Some small communities in the northern part of the Platte River Basin have had to develop mitigation plans to address exceedances for naturally occurring radium, uranium and/or arsenic in their public water systems (WWC, 2011; Olsson Associates, 2008).

Significant quantities of oil and gas have been developed in the Bear River Basin primarily in the areas around Evanston, including the Bear River Divide and drainages west of Evanston (**Fig. 5-4**). **Figure 5-7** shows that minimal coal, uranium, and metal mines exist in the Bear River Basin. Mapped coal mines are primarily historic pit mines, while a single historic uranium mine/pit was located near Sulphur Creek reservoir.

The Wyoming State Geologic Survey (WSGS) has evaluated many Wyoming sites for potential mineral development. These include precious metals (Hausel, 1989, 2002), gemstones (Hausel and Sutherland, 2000), base metals (Hausel, 1993, 1997), industrial minerals (Harris, 1996), coal (Jones and others, 2011), coal bed natural gas (WSGS, 2005), and petroleum (Lynds, 2013). Mineral development in the Bear River Basin as a source of potential contamination to groundwater resources is discussed further in **Chapter 5**.

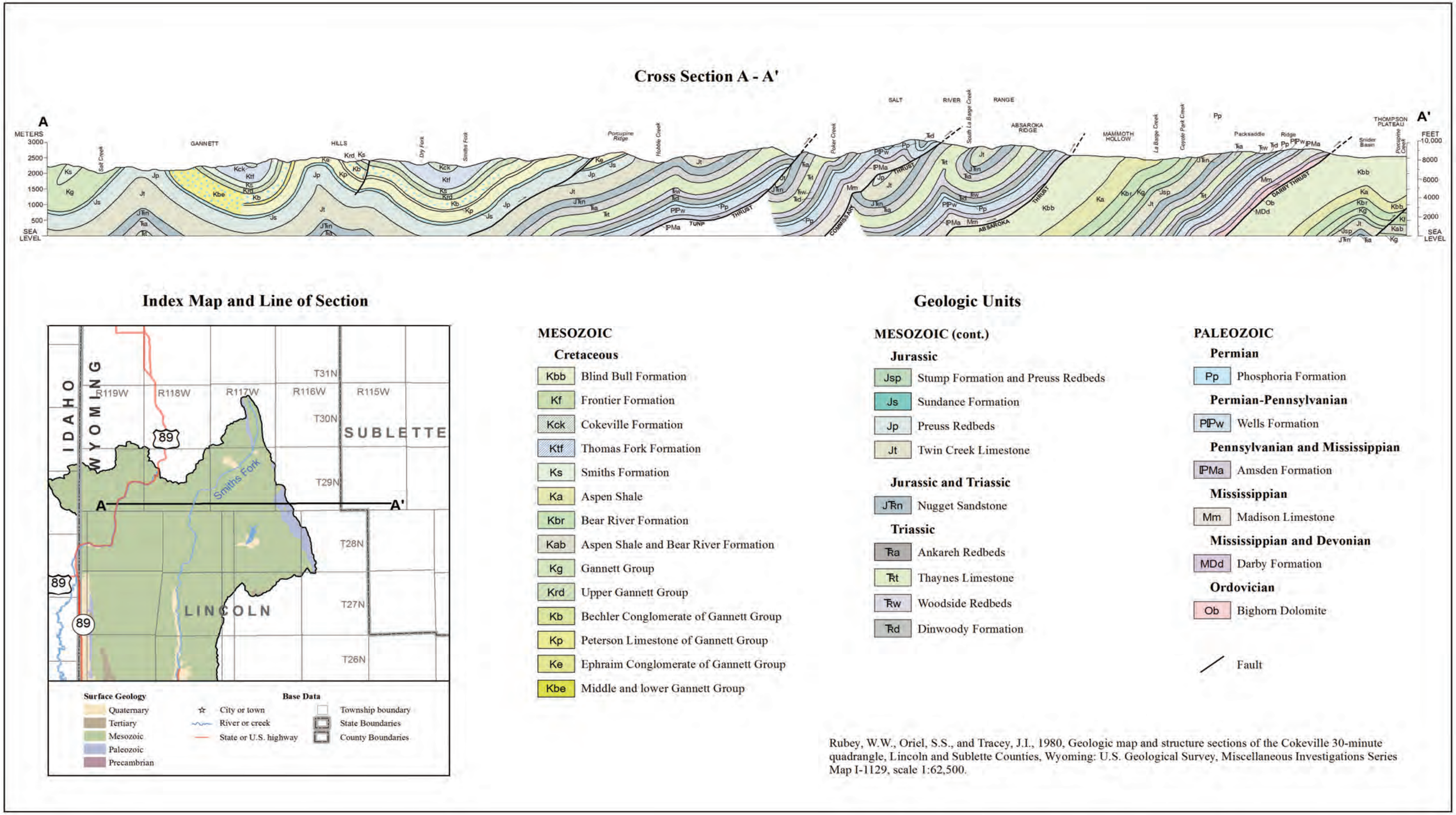
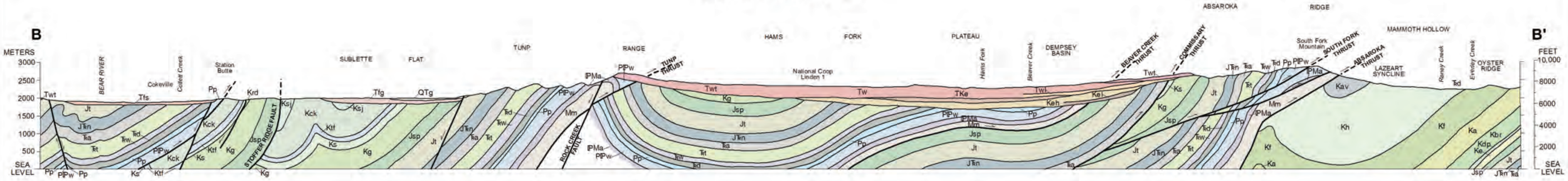
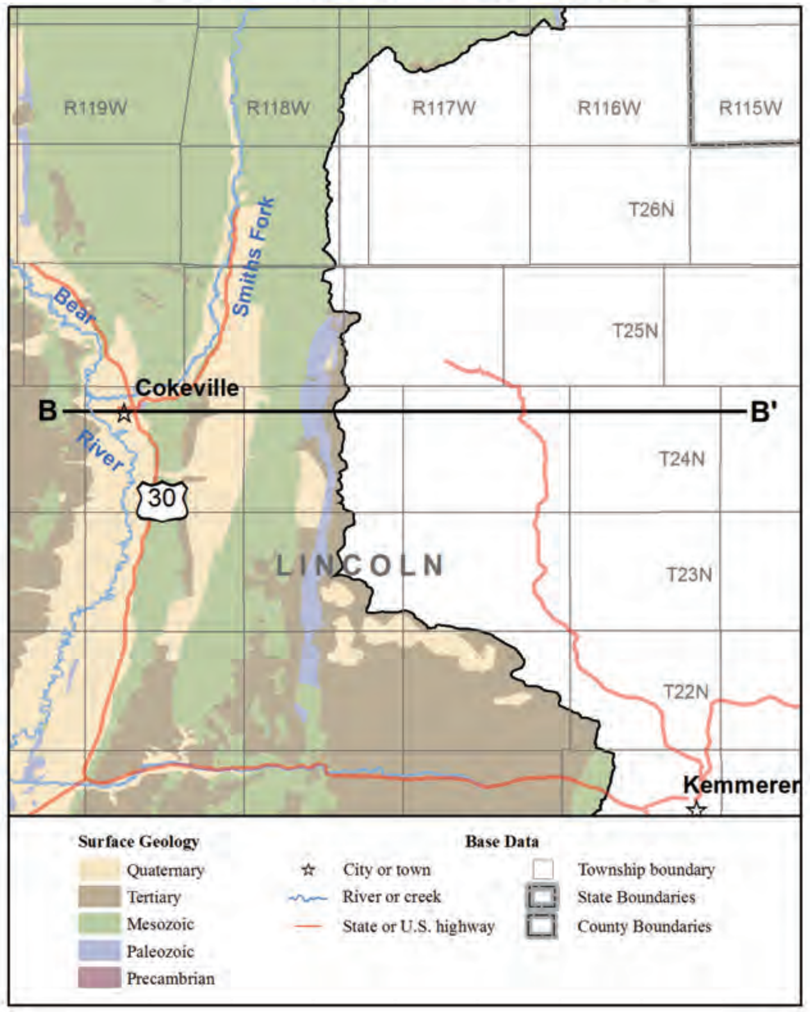


Figure 4-2. Geologic cross section A-A'.

Cross Section B - B'



Index Map and Line of Section



Geologic Units

CENOZOIC

Quaternary and Tertiary

- QTg Older gravel deposits

Tertiary

- Tfg Gooseberry Member of Fowkes Formation
- Tfs Sillem Member of Fowkes Formation
- Twt Tunp Member of Wasatch Formation
- Tw Wasatch Formation
- Twl Lower member of Wasatch Formation

CENOZOIC AND MESOZOIC

Tertiary and Cretaceous

- TKe Evanston Formation

MESOZOIC

Cretaceous

- Keh Hams Fork Conglomerate Member of Evanston Formation
- Kel Lower member of Evanston Formation

MESOZOIC (cont.)

- Kav Adaville Formation
- Kh Hillard Shale
- Kf Frontier Formation
- Ksj Sage Junction Formation
- Kck Cokeville Formation
- Ktf Thomas Fork Formation
- Ks Smiths Formation
- Ka Aspen Shale
- Kbr Bear River Formation
- Kg Gannet Group
- Krd Upper Gannet Group
- Ke Ephraim Conglomerate
- Kdp Upper Gannet Group including Bechler Conglomerate and Peterson Limestone

Jurassic

- Jsp Stump Formation and Preuss Redbeds
- Jt Twin Creek Limestone

MESOZOIC (cont.)

Jurassic-Triassic

- JTRn Nugget Sandstone

Triassic

- TRa Ankareh Redbeds
- TRt Thaynes Limestone
- TRw Woodside Redbeds
- TRd Dinwoody Formation

PALEOZOIC

Permian

- Pp Phosphoria Formation

Permian and Pennsylvanian

- PPw Wells Formation

Pennsylvanian and Mississippian

- PMa Amsden Formation

Mississippian

- Mm Madison Limestone

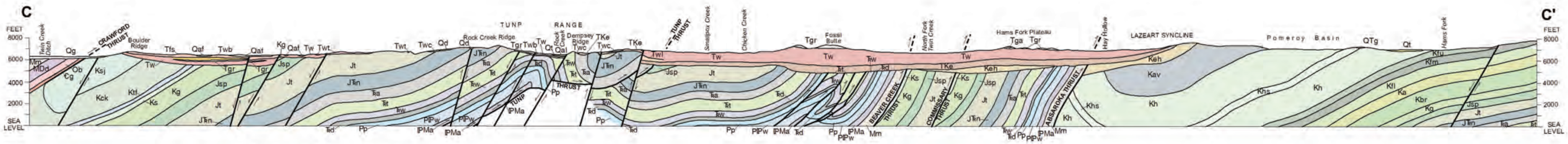
Fault

Rubey, W.W., Oriel, S.S., and Tracey, J.I., 1980, Geologic map and structure sections of the Cokeville 30-minute quadrangle, Lincoln and Sublette Counties, Wyoming: U.S. Geological Survey, Miscellaneous Investigations Series Map I-1129, scale 1:62,500.

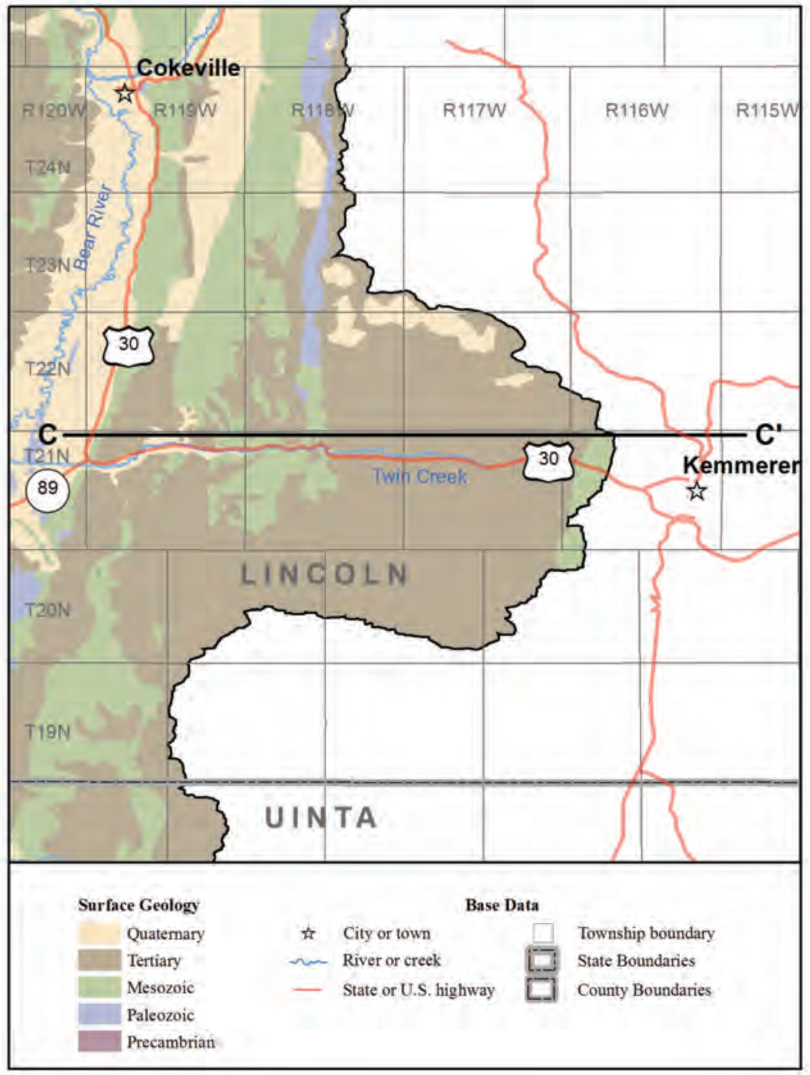
Figure 4-3. Geologic cross section B-B”.

4-33

Cross Section C - C'



Index Map and Line of Section



Geologic Units

CENOZOIC

Quaternary

- Qal Channel and flood-plain deposits
- Qaf Alluvium, colluvium, and alluvial fans
- Qd Talus and sloped rubble
- Qt Terrace deposits
- Qg Gravel

Quaternary-Tertiary

- QTg High terrace deposits

Tertiary

- Tfs Sillem Member of Fowkes Formation
- Tgr Main body of Green River Formation
- Tga Angelo Member of Green River Formation
- Twt Tunp Member of Wasatch Formation
- Twb Bullpen Member of Wasatch Formation
- Tw Main body of Wasatch Formation
- Twl Lower member of Wasatch Formation
- Twc Basal Conglomerate Member of Wasatch Formation

CENOZOIC AND MESOZOIC

Tertiary-Cretaceous

- TKe Evanston Formation

MESOZOIC

Cretaceous

- Keh Hams Fork Conglomerate of Evanston Formation
- Kav Adaville Formation
- Kh Hillard Shale
- Khs Shurtliff Sandstone Member of Hillard Shale
- Kfu Frontier Formation, upper unit
- Kfm Frontier Formation, middle unit
- Kfl Frontier Formation, lower unit
- Ksj Sage Junction Formation
- Kck Cokeville Formation
- Ktf Thomas Fork Formation
- Ks Smiths Formation
- Ka Aspen Shale
- Kbr Bear River Formation
- Kg Gannet Group

Jurassic

- Jsp Stump Sandstone and Preuss Redbeds
- Jt Twin Creek Limestone

Jurassic and Triassic

- JŦn Nugget Sandstone

MESOZOIC (cont.)

Triassic

- Ŧa Ankareh Redbeds
- Ŧt Thaynes Limestone
- Ŧw Woodside Red Beds
- Ŧd Dinwoody Formation

PALEOZOIC

Permian

- Pp Phosphoria Formation

Permian and Pennsylvanian

- PIPw Wells Formation

Pennsylvanian and Mississippian

- IPMa Amsden Formation

Mississippian

- Mm Madison Limestone

Mississippian and Devonian

- MDd Darby Formation

Ordovician

- Ob Bighorn Dolomite

Cambrian

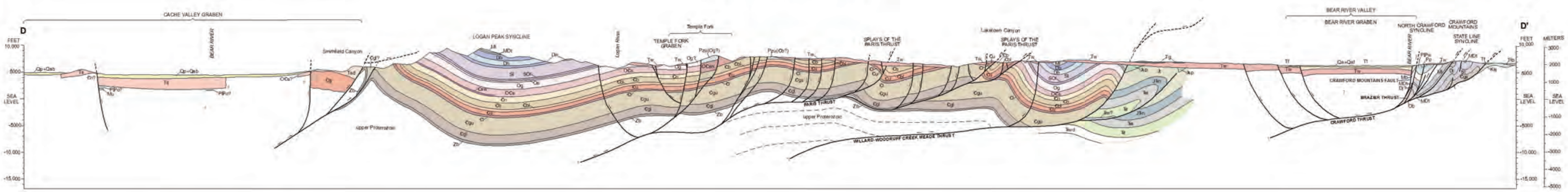
- €g Gallatin Formation

Fault

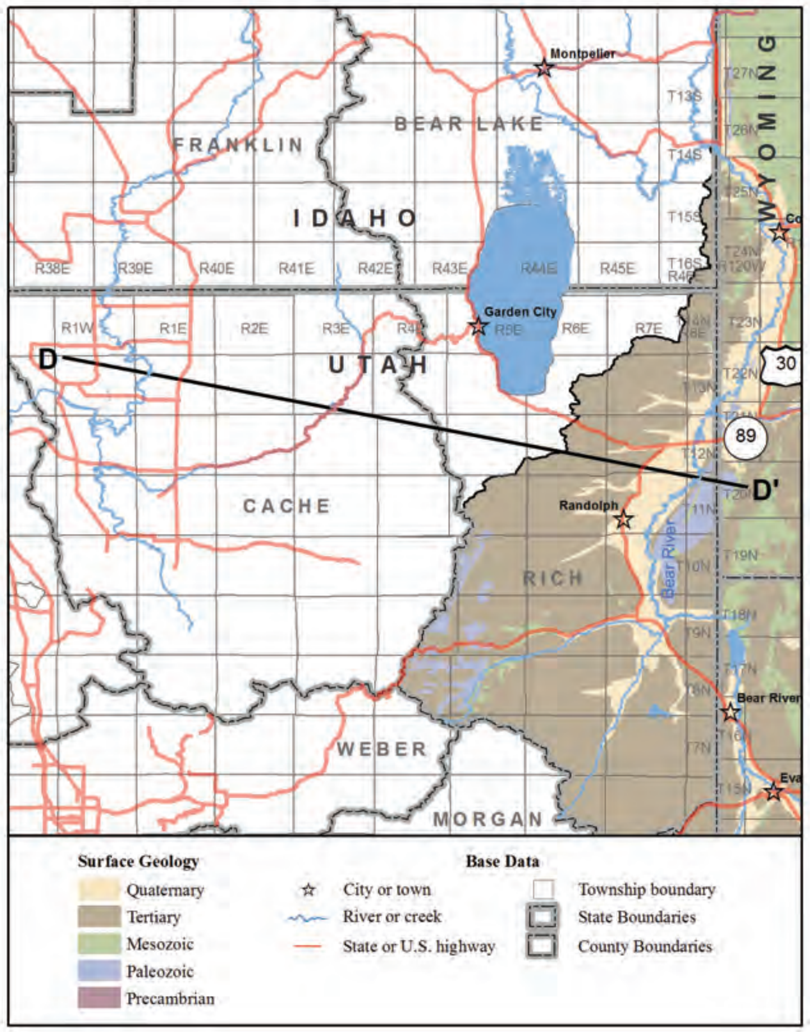
Rubey, W.W., Oriel, S.S., and Tracey, J.I., Jr., 1975, Geology of the Sage and Kemmerer 15 minute Quadrangles, Lincoln County, Wyoming: Wyoming State Geological Survey, Reprint 38, scale 1:62,500.

Figure 4-4. Geologic cross section C-C'.

Cross Section D - D'



Index Map and Line of Section



Geologic Units

CENOZOIC

Quaternary

- Qa+Qaf — Main and side-stream alluvium and fan deposits
- Qp+Qab — Provo, Alpine, and Bonneville Formations

Tertiary

- Ts — Salt Lake Formation
- Tsd — Diamictite facies
- Tf — Fowkes Formation
- Tfb — Bulldog Hollow Member of Fowkes Formation
- Tw — Wasatch Formation
- Tg — Gannett Group

MESOZOIC

Cretaceous

- Ksj — Sage Junction Formation

Jurassic

- Jsp — Stump Formation and Preuss Redbeds
- Jt — Twin Creek Limestone

Jurassic and Triassic

- JTRn — Nugget Sandstone

Triassic

- TRa — Ankareh Redbeds
- TRt — Thaynes Limestone
- TRw — Woodside Redbeds
- TRwd — Woodside Redbeds and Dinwoody Formation

PALEOZOIC

- Pzu — Paleozoic rocks, undivided

Permian

- Pp — Phosphoria Formation

Permian and Pennsylvanian

- PIPo — Oquirrh Formation
- PIPw — Wells Formation

Mississippian

- Mu — Mississippian rocks, undivided
- Mb — Brazer Dolomite
- Ml — Lodgepole Limestone

Mississippian and Devonian

- MDt — Three Forks Formation

Devonian

- Dj — Jefferson Formation
- Db — Beirdneau Formation
- Dh — Hyrum Dolomite
- Dw — Water Canyon Formation

Silurian

- Sl — Laketown Dolomite

Silurian and Ordovician

- SOf — Fish Haven Dolomite

PALEOZOIC (cont.)

Ordovician

- Ob — Bighorn Dolomite
- Os — Swan Peak Quartzite
- Og — Garden City Formation

Ordovician and Cambrian

- O€s — St. Charles Formation
- O€sn — St. Charles Formation and Nounan Dolomite
- €sw — Worm Creek Quartzite Member of St. Charles Formation
- €ga — Gallatin Limestone
- €n — Nounan Dolomite
- €b — Bloomington Formation
- €bl — Blacksmith Formation
- €u — Ute Formation
- €l — Langston Dolomite
- €g — Geertzen Canyon Quartzite
- €gu — Upper Member of Geertzen Canyon Quartzite
- €gl — Lower Member of Geertzen Canyon Quartzite

Proterozoic

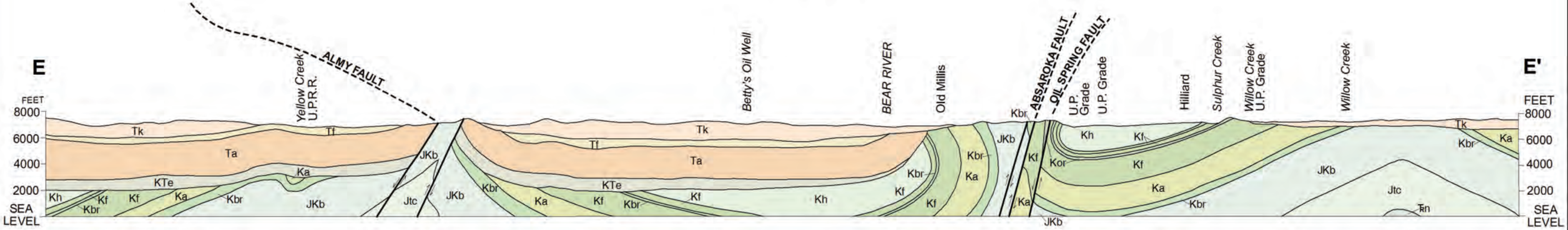
- Zb — Browns Hole Formation

Fault

Dover, J.H., 2007, Geologic map of the Logan 30' x 60' quadrangle, Cache and Rich Counties, Utah, and Lincoln and Uinta Counties, Wyoming: Utah Geological Survey, Miscellaneous Publication 06-8DM, scale 1:100,000.

Figure 4-5. Geologic cross section D-D'.

Cross Section E - E'



Index Map and Line of Section

Geologic Units

CENOZOIC

Tertiary

- Tk — Knight Formation
- Tf — Fowkes Formation
- Ta — Almy Formation

CENOZOIC AND MESOZOIC

Tertiary and Cretaceous

- KTe — Evanston Formation

MESOZOIC

Cretaceous

- Kh — Hillard Formation
- Kf — Frontier Formation
- Kor — Oyster Ridge Sandstone Member of Frontier Formation
- Ka — Aspen Formation
- Kbr — Bear River Formation

CENOZOIC (cont.)

Cretaceous and Jurassic

- JKb — Beckwith Formation

Jurassic

- Jtc — Twin Creek Formation

Triassic

- Ŧrn — Nugget Formation

Fault

Veatch, A.C., 1907, Geography and geology of a portion of southwestern Wyoming with special reference to coal and oil: U.S. Geological Survey, Professional Paper 56, scale 1:125,000.

Figure 4-6. Geologic cross section E-E'.